IMPLEMENTATION PLAN FOR THE DISTRESS ALERTING AND LOCATING SYSTEM

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THESIS

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ABSTRACT

Maritime search and rescue (SAR) is hampered by difficulty in knowing that a vessel is in distress, identifying the vessel, determining its location, and directing a rescue unit to the scene. The United States Coast Guard has developed and is evaluating an electronic Distress Alerting and Locating System (DALS). Basically this system is comprised of a remote unit on the distressed vessel, which transmits an emergency call, identification, and geographic coordinates from Loran-C and Omega. This data is relayed through a shore mounted translator to a base station where a computer interprets the information and vectors a rescue craft to the scene. This thesis describes the nature of the SAR problem, evolution of the DALS, identification of the problems inherent in the system, and a systematic plan for implementation.

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I. INTRODUCTION

Among the many and varied missions of the United States Coast Guard, none is better known than search and rescue (SAR). In an average year the service will perform almost 50,000 SAR sorties, providing assistance to about 44,000 people, and actually saving the lives of about 4,000 of them. Property saved in these SAR incidents is valued at about four billion dollars annually.

Much of this activity can be explained by simple national economic growth, which requires increased use of the waterways and the high seas. Most search and rescue however, is directed toward recreational boats, whose numbers have increased explosively over the past fifteen years. Indeed, some 90% of all SAR cases take place within twenty miles of land (Appendix A.)

II. NATURE OF THE PROBLEM

The actual rescue of a distressed vessel in most cases presents no particular problem to a properly trained and properly equipped Coast Guard unit. Unfortunately, the rescue is only the culmination of the sometimes complicated and nearly always time-consuming searching process.

The first requirement in any SAR incident is that the Coast Guard be notified that a distress is taking place. Even this is not necessarily simple, for vessels are still known to disappear suddenly and without a trace. Radio has made it possible for a boater to report his own distress instantly, but most small boats do not have this feature.

SAR cases may be also initiated by a nearby boater reporting a distress he observed, a report of an overdue vessel, or a patrolling Coast Guard unit's being on the scene of an emergency.

Assuming a distress has been reported, the problem can be simplified (or made more emergent) if the Coast Guard knows who is in trouble (one person or many), what to look for (yacht or a rowboat), and what the nature of the distress may be (sinking, burning, capsizing, grounding, breakdown, man overboard, etc.)

The weakest piece of information in most SAR cases is the location of the distress. Rarely is a good fix available. Marine navigation is an inexact science, and it is at its worst when practiced by an inexperienced or ill-equipped boat operator. Coast Guard units usually go to the reported or most likely position, and if they do not find the distress they commence a search.

Over the years, overwater searching has developed into a polished art, as an attempt to solve the "needle in a haystack" problem. Various search patterns and combinations of air and surface units will be employed depending upon the object of the search, what is already known about its location or intentions, how much time has elapsed in the incident, and the prevailing weather and sea conditions. With all the variables coming into play, the probability of detection also becomes highly variable.

While these procedures have worked successfully for many years, in too many cases they are wasteful of time and money, and the inaccuracies involved may cause a possible rescue to be a failure. The effort spent on one incident (even a false alarm) may preclude successful prosecution of another. The process could be improved significantly by a system which would announce that a distress is happening, identify

the distressed unit, tell the location accurately, and vector rescue forces to the scene.

III. PREVIOUS ATTEMPTS AT A SOLUTION

The concept of a precision navigation system to locate a relatively small object in a relatively large and trackless area is not limited to the Coast Guard's interest in SAR (although that is the only topic covered in this thesis). For instance, a similar system could be used to position buoys with great accuracy, and to report if they drift off station. Ships could use it to find their way up a narrow channel when conventional aids to navigation were useless due to fog or ice. It could vector helicopters off icebreakers to search for open water or off destroyers to attack submarines. The movement of radiosonde weather balloons could be tracked, astronaut splashdowns could be pinpointed, and lost hunters could be found in the woods.

Search and rescue over water is still the critical area for the Coast Guard. The one leap forward in this area has been in radio direction finding, where rescue units home in on transmissions from the distressed party. This assumes that the vessel in distress makes such transmissions and they are heard. Both the U. S. Navy and the Federal Communications Commission operate radio direction finding nets which can be pressed into use in a SAR case. Coast Guard ships, boats, and aircraft also have radio direction finders to home on a distress signal. Recently, many aircraft and some ships have been equipped with Emergency Position Indicating Radio Beacons (EPIRB's), which, when activated, transmit a coded signal on a distress frequency. Unfortunately, their life is short and range limited. The vagaries

of radio propagation are such that any RDF activity can provide only a very general location of a distress (the best fixes are accurate to about 20 miles) and the search must start from there.

In 1967 the National Aeronautics and Space Administration, working on the Project Apollo (moon landing) program commenced development of a system to locate a space capsule (and its astronauts) should it be forced to return to earth in a location other than that of the recovery task force. The NASA project, code-named OPLE (for Omega Position Location Equipment) resulted in a device which received Omega electronic navigation signals appropriate to its position and then retransmitted them to a satellite, which in turn relayed the signals to a base station ashore, theoretically making it possible to locate a downed spacecraft wherever it might be.

The NASA concept was seized upon by the Naval Air Test Center, Patuxent River, Maryland, which had hopes of applying its technology to more mundane uses. It acquired the name GRAN (for Global Rescue Alarm Net) and it was planned that someday all ships, boats and aircraft would have GRAN transmitters to fix their position in the event of a distress anywhere in the world.

Two problems, one technical and one political, hamper development of GRAN at present. The technical problem concerns Omega, the hyperbolic electronic navigational system which generates the signals which GRAN retransmits. Omega covers the whole globe, but in some areas, unless the navigator already has an approximate idea of his position, the Omega signal can only narrow down the position to a lane 72 nautical miles wide. This is not normally a problem to the navigator, but it is to a search unit. Secondly, because GRAN would be worldwide, there

would have to be numerous international agreements about equipment configuration, cost sharing, areas of SAR responsibility, mutual cooperation and the like. These problems alone could delay implementation for years.

IV. DEVELOPMENT OF THE DISTRESS ALERTING AND LOCATING SYSTEM

At about the same time as the NASA experiments, the U. S. Department of Commerce (ESSA-Weather Bureau) was experimenting with means to determine wind direction and velocity by tracking weather balloons. Their equipment used a combination of Loran and Omega signals, remotely retransmitted. This came to the attention of the Coast Guard, which was also concerned about tracking weather balloons launched from cutters at sea. The Coast Guard had been concentrating on a high resolution balloon-tracking radar, experiments with which had shown it to be complicated, costly, unreliable, and generally unsuccessful.

In 1969, Beukers Laboratories, Inc., of Hauppauge, New York, approached the Coast Guard with a new proprietary system called LO-CATE (Loran-Omega-Course-and-Track-Equipment). The LO-CATE received Loran-C and Omega signals and retransmitted them to a base station where the position of the retransmitter was automatically computed. Application to the balloon tracking problems was obvious, and Coast Guard search and rescue experts believed the LO-CATE concept could be extended to SAR.

In August 1970 Beukers and the Coast Guard conducted joint tests of the LO-CATE system at Fire Island Coast Guard Station, Long Island, New York. A base station was set up in the main building at the

Coast Guard station, a LO-CATE retransmitter (the remote unit) was deployed in a 40-foot Coast Guard utility boat, and Loran-C and Omega receivers and a frequency translator were installed in a Coast Guard helicopter. (The frequency translator relayed signals from the boat's retransmitter to the base station, and also sent the helicopter's position to the base station.)

The test involved having the helicopter fly a prearranged pattern and having the base station operator mark its progress on a chart. During the couse of the test, the boat crew would switch on their retransmitter, and the base station operator would vector the helicopter to the boat, simulating the search for a boat in distress. The system functioned properly; the helicopter was tracked and vectored accurately and the boat was located successfully.

This test stimulated a continuing interest at the Coast Guard, and plans were formulated in the Office of Research and Development to expand LO-CATE into a Distress Alerting and Locating System (DALS). The Coast Guard R. & D. Center, Avery Point, Connecticut, is testing a modified LO-CATE in 1973 for use in DALS, as well as for use as a navigational aid and for use in harbor traffic control. It is estimated these tests will be completed and plans and specifications for a complete system for operational use will be ready by 1976.

The DALS as presently conceived consists of three major subsystems.

The retransmitter is the unit installed aboard boats. When turned on, it receives Loran-C and Omega signals and retransmits them (at present on an experimental frequency; ultimately on a distress/calling frequency) along with a distress call and identifying signal. To

permit all retransmitters an equal chance to send their message they are programmed randomly to switch on at different times; this minimizes the chance of one unit interfering with another.

The translator serves two purposes: to relay signals from the remote retransmitters, and to fix the position of a rescue vehicle working on the search. When the translator is relaying signals from the retransmitter, it merely sends them over a selected frequency (or land line) to the base station, thereby extending the retransmitter's range (which is normally line-of-sight because of its VHF emissions). It is envisioned that translators such as this would be permanently shore mounted to provide coverage over all waters up to twenty miles offshore. When the translator is serving as a position fixer (such as when it is mounted in a rescue boat or helicopter) it would be coupled to Loran-C and Omega receivers, and would transmit its own position back to the base station.

The base station equipment is centered around a computer which receives the signals from the translators and gives the operator a printout (either numerically or directly on a chart) of where the distressed vessel and rescue units are located. The base station operator will use this information to vector the rescue unit to the distress. Base stations will be located at Coast Guard units where it is most efficient for them to work on the signals from the translators.

V. SPECIFIC PROBLEMS TO BE RESOLVED

Before any DALS system is implemented, several unresolved and highly significant questions must be answered.

First among the questions is whether DALS equipment will be optional or mandatory for the 45 million vessels which use our coastal waters. Since 90% of SAR cases occur within 20 miles of shore, these coastal waters are where coverage is most needed. The DALS translators and base stations will be an expensive investment for the Coast Guard, and the investment should not be made if there will be no "customers" to make use of it.

If DALS retransmitters (remote units) are optional, there will no doubt be many boaters who will purchase them and even use them in emergencies. Unfortunately, the type of boatman who would do this is the type who already has extra safety equipment, knows his seamanship well, and usually does not get in trouble on the water. The operator who runs aground through ignorance probably will not even have a life jacket on board, much less a DALS retransmitter. Although DALS would get some use under a voluntary arrangement, it would seem likely that it would not serve the people who need help the most.

The alternative is to make DALS mandatory on all vessels (or those over a certain size or power) operating on federal waters. There is no need for DALS on state waters such as lakes, because any search area is clearly delimited, and the Coast Guard does not serve such waters. Mandatory DALS carriage opens several new problem areas, although it does ensure that all waterways users will get DALS service.

First is the unit cost question. In the early stages of the R. & D. program it was hoped to keep the cost of the retransmitter under $50.00. The cost must be reasonable if all boaters have to have one, and with 45 million vessels to equip, the potential for mass production savings is certainly apparent. The prototype DALS transmitter looks like a compact walkie-talkie; it is, however, a moderately complex piece of electronic gear. It must receive both Loran-C and Omega signals (it does not have to interpret them.) It must transmit a distress call, identification, and the navigational information, and the transmission must be randomly timed to minimize the possibility of interference with another unit. It is potentially very expensive. When the R. & D. project is far enough along to have firm specifications for an operational retransmitter, Coast Guard electronics engineers and proprietary manufacturers should confer to determine what the commercial price of the retransmitters will be. How high the price is to the average boater will solve the optional/mandatory problem. If mandatory carriage is the answer, the Coast Guard will have to draft and introduce the enabling legislation.

There may be fears that having every boat equipped with a transmitter linked directly to a government agency may be a step towards the all-seeing "telescreen" in Orwell's <u>1984</u>. There is no requirement that anyone use his DALS; he will only have to carry it. The unit is small enough to be hidden out of the way if the boat owner does not like it. A precedent has been set by mandatory carriage of life jackets and fire extinguishers; they only have to be on board; no one is required to use them.

If all vessels have DALS, there may be a strong upsurge in the

amount of search and rescue activity. At present much potential SAR goes unreported. Many distressed boats are saved, towed, or repaired by civilians without the Coast Guard's ever being notified. If a boat has DALS aboard, though, the operator will be strongly tempted to use it to call the Coast Guard at the first sign of trouble. In this sense DALS is like the familiar corner fire alarm box. It can only announce that there is trouble, and cannot say how bad the situation is. This problem should be weighed carefully in the light of the present budget retrenchments and changing mission areas. Already some SAR facilities are hard pressed to meet their work load, and there is little relief (in more people or equipment) in sight for them. The Coast Guard may not be able to afford the improved public service it seeks to provide. To be sure, DALS will reduce search time, but twenty one-hour searches will take as much operating time as one twenty-hour search.

A related problem concerns the absolute cost of the DALS equipment the Coast Guard will need itself to provide the requisite coverage. This will undoubtedly run into millions of dollars, and DALS will have to compete with established and more pressing programs in the budgetary arena. There is substantial doubt that DALS could survive in the present tight budget climate. If DALS participation were required of the public, the CoastGuard would be obligated to provide its portion of the system, even at the expense of the other programs.

Another consideration to be weighed in implementing DALS is the extra requirement it will generate for training and maintenance. The base stations will be operated by enlisted men at small units, and they will need a thorough training program. Also the base stations, the translators on boats and aircraft, and the shore mounted translators

are going to need both repairs and regular maintenance. This may require an increased number of electronics technicians; men who are already in short supply. When funds are requested to implement DALS, these personnel must be included.

At first it would appear that DALS would be susceptible to false alarms, since a push of the button on the retransmitter is all it takes to call out the Coast Guard. Every DALS signal includes an identification pulse and this will make it possible to trace the perpetrator of a false alarm. False alarms from DALS would appear to be covered by the same Federal Communications Commission regulations as spurious distress calls on conventional radio frequencies.

A problem may arise in the choice of a frequency on which DALS will operate. The prototypes have used frequencies reserved for electronic experimentation. Thought has been given to having DALS operate on 156.8 MHz, the maritime mobile distress and calling frequency in the VHF-FM band. While DALS could certainly justify its presence on 156.8 MHz, this may not be workable. There is already heavy voice traffic on this frequency and nobody knows what will happen if the DALS translators start picking up spurious voice signals and sending them to the base station computer. Furthermore a legitimate DALS signal could well be drowned out by normal voice transmissions. The on-going R. & D. project will investigate this problem. An obvious solution is for the Coast Guard, going through the proper channels, to request Federal Communications Commissions to assign a separate frequency for DALS use. Because of the line-of-sight transmissions this will be a problem of the United States only. If at some time in the future DALS is incorporated into a world wide satellite-relay

Global Rescue Alarm Net, (GRAN) there is a frequency available: 406.1 MHz is reserved for satellite search and rescue.

Concern has been voiced about one DALS retransmitter interfering with another if two distresses happen near one another at the same time. This is probably an overrated problem. If there are 40,000 search and rescue incidents a year, that reduces to 109 a day, or less than five an hour, across the entire United States. Admittedly SAR cases tend to bunch up geographically (where there are the most boats) and in time (Sunday afternoons and holidays in particular). The feature of the DALS retransmitter in which different units key their transmissions at random different times should reduce this potential problem to nearly zero in reality.

If DALS is adopted there will have to be some standard operating procedures promulgated to users. For instance, a boat with a radio should call the Coast Guard in the tranditional method as well as keying its DALS in order to provide a backup distress call, and amplifying information about what is wrong.

A decision must be reached concerning what areas DALS will cover. To provide optimum public service, DALS should cover all coastal waters off the coterminous 48 states up to 20 miles offshore. The Great Lakes should be included also. Coverage should also be provided in Alaska, Hawaii, Puerto Rico, and the Virgin Islands where the amount of boating activity warrants it (Appendix B.)

The cost of the DALS translators and base stations has not yet been determined (this will be a product of the current R. & D. work), but the equipment will be expensive enough that the system will probably have to be phased in over an extended period. Installation

should be made first in the areas where there is the most SAR activity. To illustrate examples of extremely high and low SAR density, a geographic density plot of fiscal year 1971 SAR cases was produced on a CDC 3300 computer by Search and Rescue Division, U. S. Coast Guard Headquarters. Appendix A shows SAR density and the need for DALS in different geographic areas.

Before any installations start, two engineering surveys should be undertaken. One of these would determine if there is adequate Loran-C and Omega reception in all areas for the DALS retransmitters to function properly. The second would determine where to place the translators so as to have line-of-sight coverage over the entire planned coastal area (Appendix B.) This second survey will also give an indication of where to place the DALS base stations. Most base stations would probably best be located at Coast Guard Group Commanders' Offices. These offices are parent commands of small search and rescue units and have direct communication links to district Rescue Coordination Centers. Thus the Group Commander is in a pivotal position to coordinate search and rescue activities. Some groups are rather far-flung geographically, and in these areas there may be a need for base stations at smaller remote Coast Guard units (Appendix C.)

A worthwhile final evaluation would be to select one geographic area and set up a prototype DALS there for about a year to evaluate its use under field conditions. All the Coast Guard boats and aircraft there would have translators, and a selected group of Coast Guard Auxiliary boats would get the retransmitters. Assuming the area chosen was one in which the Auxiliary participates in a substantial amount of SAR, the DALS would get a thorough workout.

VI. RECOMMENDED IMPLEMENTATION PLAN FOR DALS

The DALS program is sufficiently expansive that it will have to be implemented in orderly phases, rather than in one simple project. Background work must be completed before actual physical installations are begun.

First, the present research and development program, currently underway and scheduled to run through 1975, must be completed. Its major thrust is to design, test, and evaluate a protype DALS. This activity must be tasked with several other assignments related to the prototype DALS, and if necessary, additional funding and time should be obtained for them.

Early in the time frame, the Coast Guard should decide what geographic areas DALS will cover. Basically, this should be all coastal waters of the United States up to 20 miles offshore (Great Lakes included), but the coverage in remote areas such as much of Alaska will be tradeoff of cost against potential lives saved (Appendix A.)

The R. & D. program should give an indication of the cost of the DALS retransmitters. This could be determined by a conference between the designers of DALS, Coast Guard engineers, and electronics firms which might produce the retransmitters. This cost, more than anything else, will determine how reasonable it will be to require every boat to carry DALS. At the same time, the cost of the DALS translators and base stations could be estimated, along with operator and repairman training requirements, and the cost of the requisite parts support. This data would be used by the search and rescue and communications

elements at Coast Guard Headquarters to determine the cost to the Coast Guard of the DALS project.

Several areas of concern could be treated in an expansion of the research and development project. An engineering survey of the entire area to be covered by DALS should be conducted to determine if the Loran-C and Omega coverage is adequate for the intended use, to locate positions for translators ashore to provide line-of-sight coverage of the entire area, to select the most efficient locations for base stations, and to recommend what links would serve best between the various base stations and their translators (Appendix B.)

Finally, the research and development effort should conclude with a recommendation for a frequency on which DALS will transmit, based on test results.

With this information in hand, the Coast Guard will have to reach a position on whether DALS will be mandatory or optional, and for whom. This decision will have to be made by the Commandant himself after consultation with his various assistants (search and rescue, communications, boating safety, legal.) The decision must be based on cost to the boating public, ability of the Coast Guard to support the system, possible legal ramifications, and other considerations which may surface. When a position is reached, the Coast Guard should start to draft enabling legislation and standard operating procedures for DALS, but they should not be released to the public until some more in-house work is completed.

Before DALS is announced to the public, the Coast Guard must be sure of its ability to support the system. Using the costs developed in the R. & D. program, the Coast Guard must determine if it can afford

the hardware, the spare parts, extra base station operators, their training, extra electronic technicians, and their training. Furthermore, estimates must be made of how many extra SAR cases will be realized because of DALS, how long the average SAR case will take to prosecute (theoretically DALS will make this quicker), and if the Coast Guard will have sufficient resources to handle the resulting load. Then the chances for DALS' survival in the budgetary arena must be weighed. Other programs which can realistically be curtailed or cancelled for DALS to succeed should be identified. Also, there must be an estimate of how many years it will take to get DALS funded and installed; public compliance cannot be required before this time.

Secure in the knowledge that it will be capable of implementing DALS, the Coast Guard should commence work on the frequency management aspects of the system. Whether DALS needs its own frequency or can operate on one which is already available (as determined through the research and development), the Coast Guard will have to approach the Federal Communications Commission and secure that agency's recommendations and ultimately its approval to operate this unique system. At the same time, the subject of DALS false alarms should be aired, and if they are not subject to exisitng prohibitions, the DALS implementing legislation should contain regulations to suppress them.

The next step is to decide in what order to install the equipment. It should go first where it is needed most. This can be accomplished by running a computer density plot for coastal SAR using the latest information. Interpretation of the printout will indicate where the DALS will be most effectively installed. A plan should be drawn, starting installations in those areas with the most SAR, and ultimately covering all the coastal waters (Appendix A.)

With this much groundwork completed, the Coast Guard should announce DALS to the public in full detail, describing the equipment, coverage, legal requirements, benefits to be derived, etc. Interest could be expected from Congress, boat owners and operators, commercial waterways users, state regulatory agencies, and companies desirous of producing DALS equipment. The announcement of DALS should also indicate that the Coast Guard was about to commence a one-year evaluation of DALS under actual field conditions.

This evaluation would be similar in format to those in which air cushion vehicles and new types of utility boats were evaluated in recent years; the DALS would be used by operational Coast Guard units in pursuit of their day-to-day missions. An area with a heavy SAR load should be selected, all Coast Guard boats and aircraft there should get translators, and a central shore unit should get the base station. Furthermore, if the area were one in which the Coast Guard Auxiliary was active in SAR, a group of Auxiliary boats should get DALS retransmitters (Appendix D.) Over the course of the year, the units should work DALS into as many operations as possible, as well as being encouraged to experiment with new uses for it. Monthly reports of activities should be made through the chain of command to the supporting office at Coast Guard Headquarters. At the end of the evaluation, the district commander should submit a summary report outlining the entire evaluation, shortcomings, and recommendations. Headquarters should use the evaluation reports in drafting final specifications for the operational DALS (Appendix C.) While the evaluation is progressingthe Coast Guard should have the DALS enabling legislation (already drafted) introduced to Congress. A detailed

installation schedule should be planned and equipment specifications finalized. The necessary budget requests should be submitted in such a time frame that system installation could begin as soon as the field evaluation was complete and legal authorization was received.

With budgetary authority received, completion of DALS will be merely a function of the contracting process.

APPENDIX A.

SAR DENSITY PLOTS

Utilizing the computer data bank at U. S. Coast Guard Headquarters it is possible to create a printout which is a plot of all search and rescue cases in a given area over a given period of time. The plot is such that the area is divided into squares (for example three degrees of latitude by three degrees of longitude), and in each square appears the number of SAR cases which occurred there during the period in question.

For this thesis a run was made utilizing data for fiscal year 1971 (the most recent available.) The attached charts show the concentration of SAR in typical high-density and low-density areas.

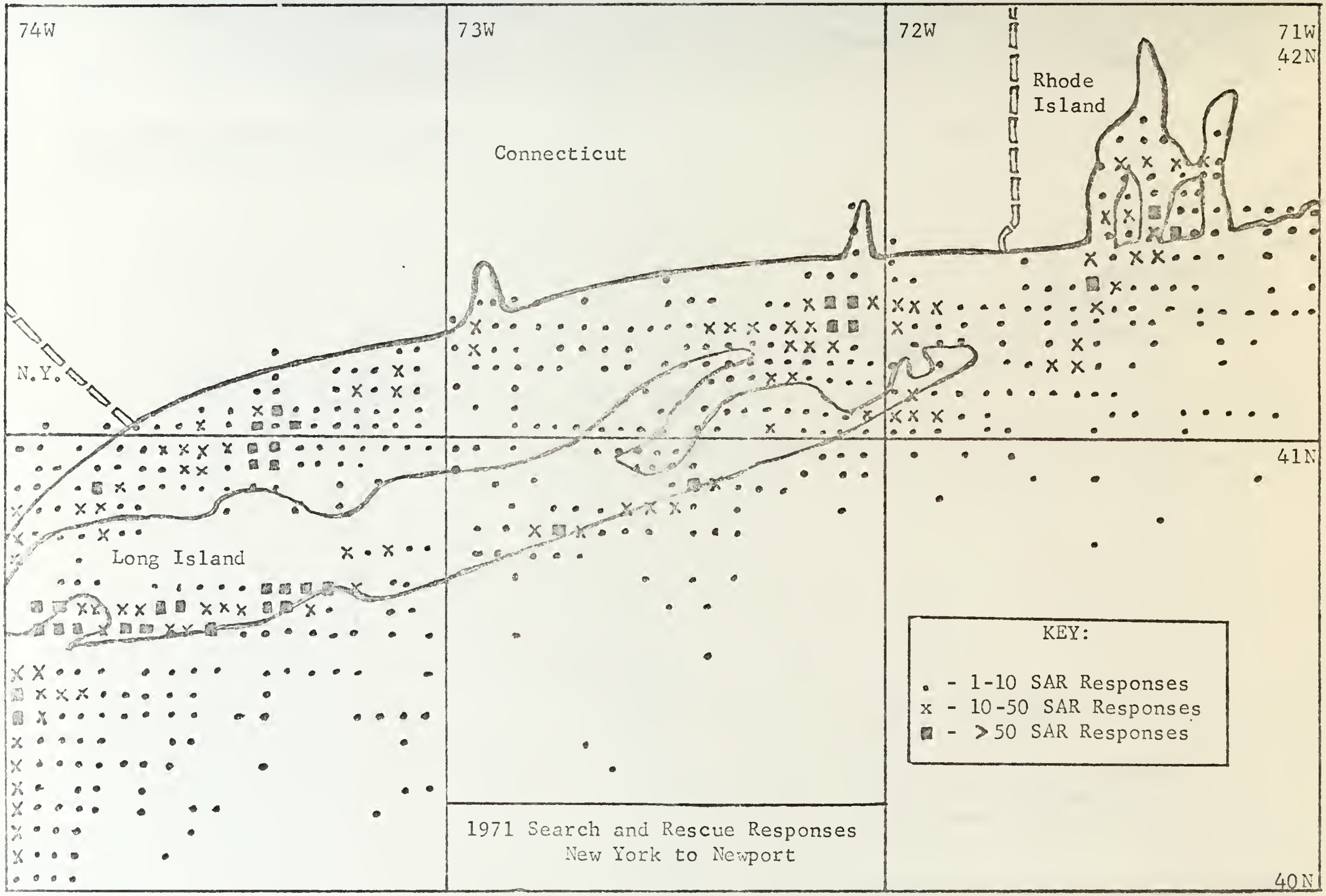
The first chart is the area from New York to Newport, Rhode Island, covering the area from 40N to 42N and 71W to 74W in three-minute increments (squares.) Because of pleasure boating and sport fishing, SAR activity is extremely high in this area. Noteworthy is the concentration within twenty miles of the shoreline, the area which DALS would serve.

The second chart is the Alaska Peninsula and Aleutian Islands, covering 40N to 60N and 160W to 180W in twenty-minute squares. In this remote area, most of the SAR involves fishing vessels or other commercial interests, and therefore is concentrated at the prime fishing grounds, not along the coastline.

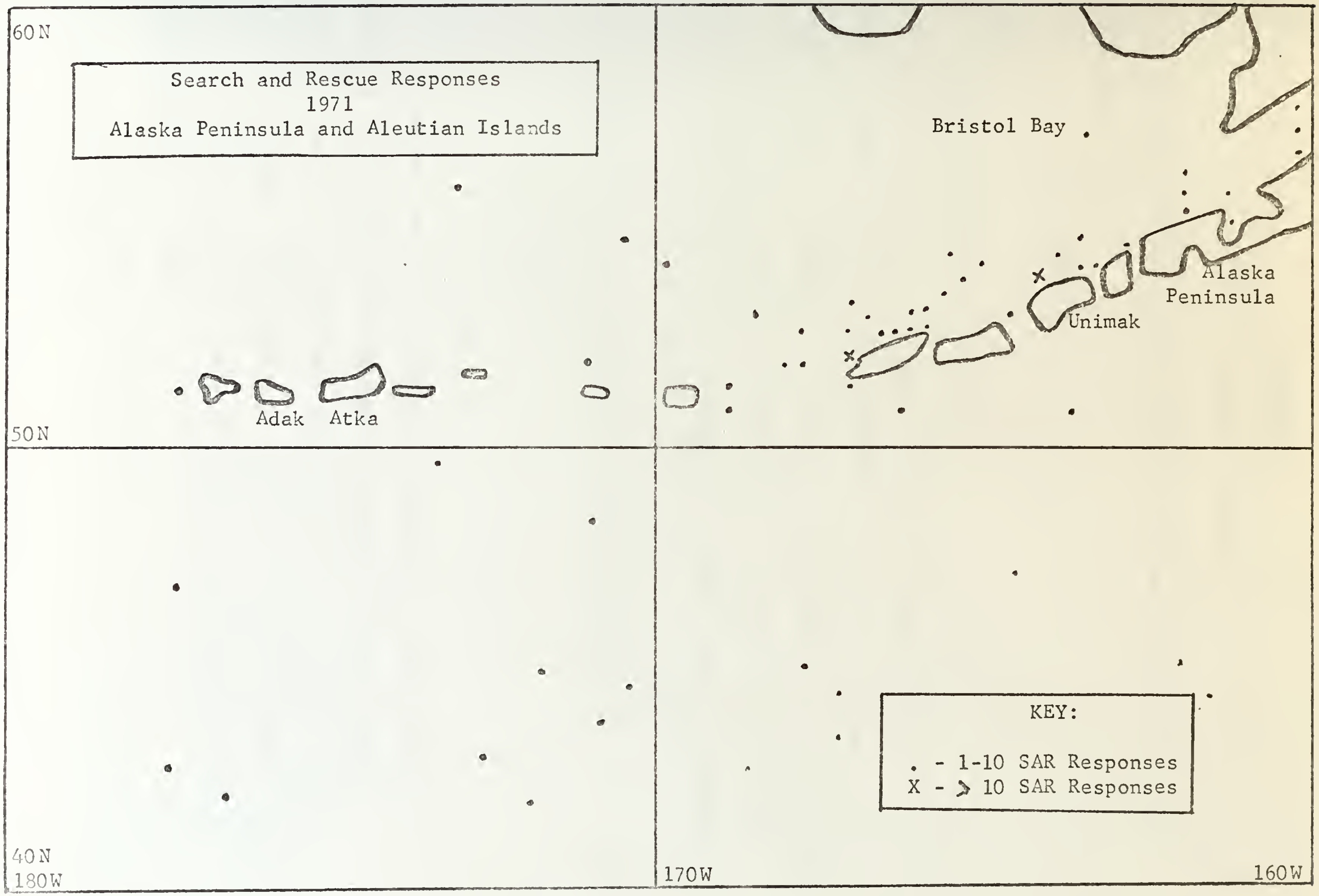
In the high density area, DALS would be a good investment, but in the low density area it would get only minimal use in a typical year.

In the implementation of DALS, similar computer runs should be made, covering all the proposed coverage areas up to twenty miles offshore. This will rapidly identify the areas of SAR concentration where the system will be needed first. At the same time, the facility manager for search and rescue should identify areas in which SAR units are hardest pressed to meet the existing workload, and which would therefore benefit most if DALS reduced search time, or which would suffer most if DALS caused an increased number of cases to be handled. The workload factor could then be considered during implementation.

The evaluation of case load in geographical areas could lead to another consideration in the debate of whether DALS should be optional or mandatory. There may be certain areas in which all vessels will be required to have DALS. This would have the effect of putting the installations where the workload was known to exist, while at the same time making no imposition on boaters in remote areas.



1971 Search and Rescue Responses
New York to Newport


Search and Rescue Responses
1971
Alaska Peninsula and Aleutian Islands
60 N
50 N
40 N
180 W
170 W
160 W
Bristol Bay
Alaska
Peninsula
Unimak
Adak
Atka
KEY:
. - 1-10 SAR Responses
X - > 10 SAR Responses

APPENDIX B.

EFFECTIVE RANGE OF ANTENNAS

The radio distance to the effective horizon is given with good approximation by

$$d = (2h)^{\frac{1}{2}}$$

where

h = height in feet above sea level

d = radio distance to the effective horizon in statute miles

when the height is very small compared to the earth's radius. A 4/3 earth's radius is assumed, as this is the best approximation to reality.

In the case of the DALS retransmitter, the prototype has a whip antenna approximately three feet high. In a small boat, the operator will hold the unit about three feet above the water, making h six feet. Therefore, the retransmitter's effective distance is

$$d = (2 \times 6)^{\frac{1}{2}}$$

$$d = (12)^{\frac{1}{2}}$$

$$d = 3.46 \text{ miles}$$

To capture the signal from the retransmitter (conservatively having a 3-mile range), and provide the desired 20-mile offshore coverage, the shore mounted DALS translators must be able to "see" 17 miles offshore. The translator antennas will need a minimum height of 144.5 feet to provide 17-mile coverage, as can be shown by these calculations

$$d = (2h)^{\frac{1}{2}}$$

$$d^2 = 2h$$

$$(17)^2 = 2h$$

$$289 = 2h$$

$$144.5 = h$$

This makes no allowance for path interference from the terrain, nearby high buildings, and so forth.

To provide continuous coverage to 17 miles offshore, the radii which the antennas could see would have to be overlapped, requiring a translator antenna every 8.5 miles along the shore. The attached chart shows seventeen translators (at the 144.5 foot antenna height) covering the area from New York to Newport.

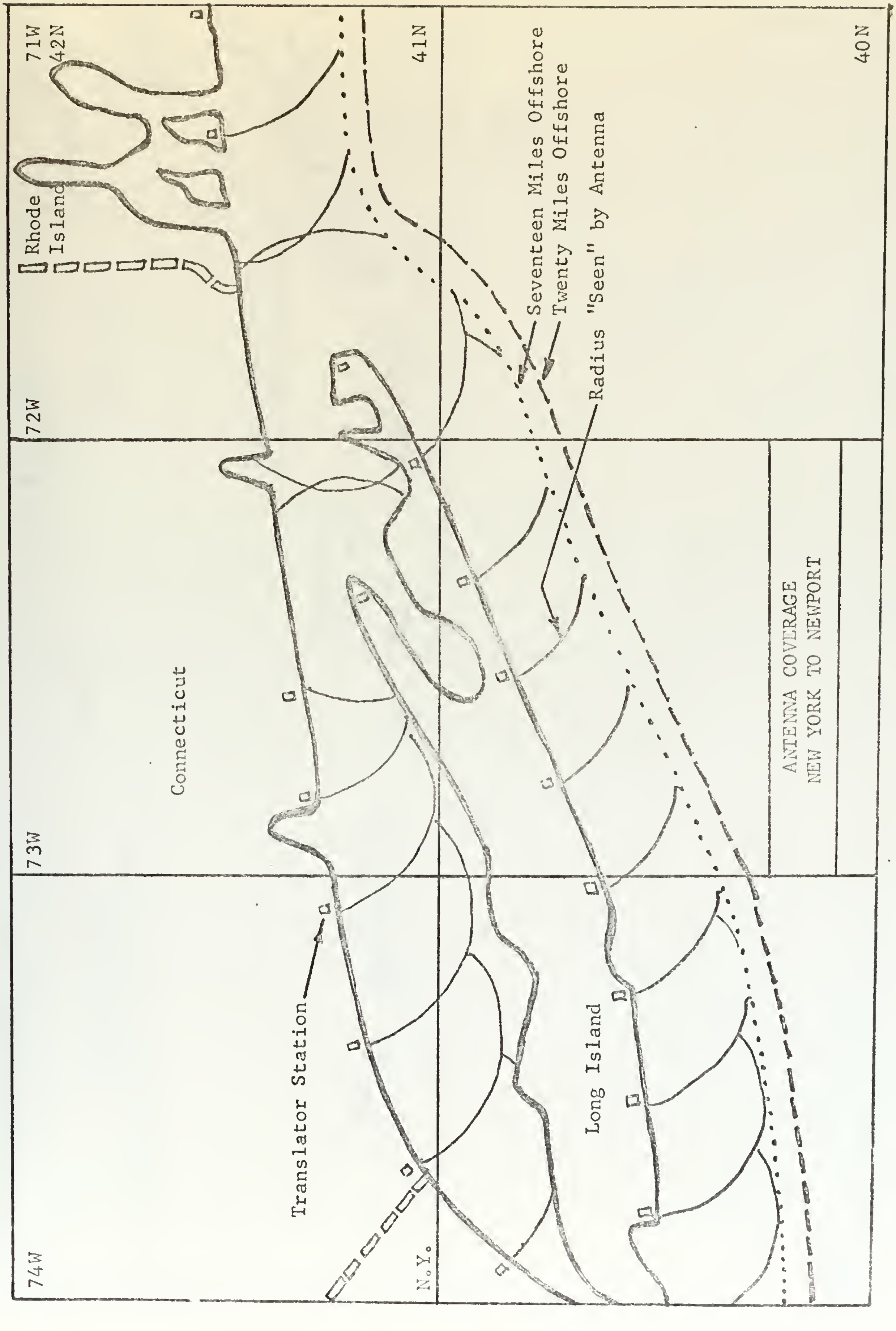
Obviously such an arrangement would require a prohibitive number of translators to cover the entire coastal zone. A workable alternative solution is to use taller antennas for the translators. This would be the subject of cost trade-offs; it must be decided for each geographical area whether a single high antenna is more effective than several smaller ones. In some districts it will be possible to mount the translators atop high cliffs or mountains, thus enabling a comparatively modest antenna to see a large area. The high antenna has a secondary benefit in that it will be able to see farther than the minimum 17 miles out to sea directly in front of its location.

An administrative problem is also visible in the New York to Newport chart. The boundary between the First and Third Coast Guard Districts is at approximately the Rhode Island and Connecticut border. On either side of this line SAR cases are handled by different Coast Guard Units (major emergencies are coordinated by Commander, Atlantic Area) supervised by different Rescue Coordination Centers. The translators near the border area should be connected so as to return their signals to the proper operational commander, with a secondary message to the adjacent commander.

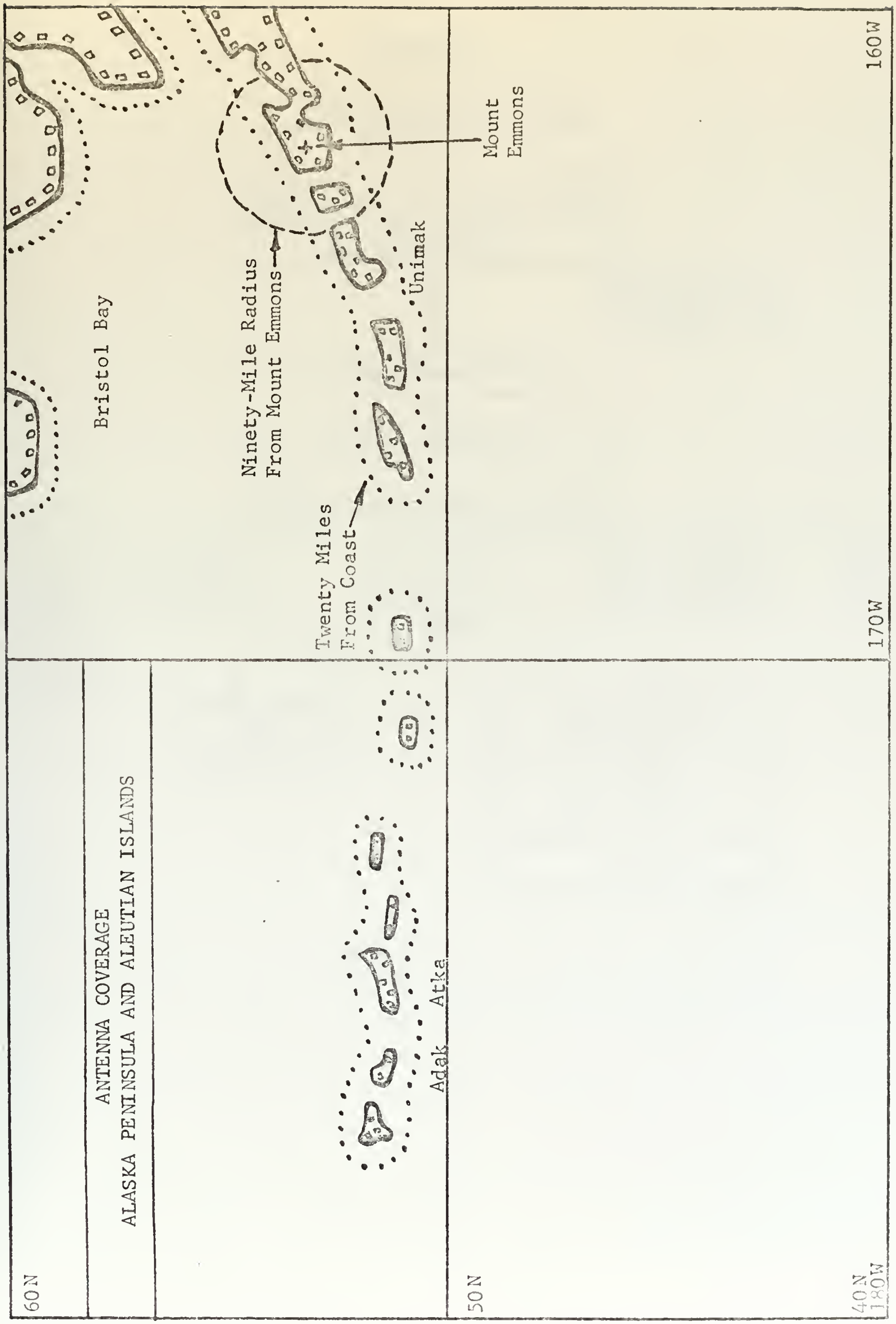
The chart of the Alaska Peninsula and Aleutian Islands shows the problems DALS will have in a low density SAR area. If the minimum 144.5 foot antennas were mounted there, it would take 80 translators to cover the 17-mile zone around the coastline shown in the chart. This is clearly impractical, for there were only 119 SAR incidents during 1971 in the entire 1,400,000 square miles shown on the chart in a year, and most of the SAR happened outside the 20-mile coastal zone. There would probably also be problems getting power and reliable communications links to so many translators in remote locations. An obvious solution is to have fewer translators, each seeing a greater area (higher antennas). In a low density SAR area such as this, it may not be practical to have total DALS coverage, and installations should be made so as to cover those areas where SAR cases have been shown to be most likely to happen. For example a translator installed at the 4000-foot level on Mount Emmons on the Alaska Peninsula could "see" 90 miles into the area of highest SAR concentration.

In remote areas, DALS could be made more effective by increasing the height of the retransmitter antenna above the distressed unit and thus its range. If the antenna were 50 feet in the air, it would have a 10-mile range. A fixed antenna of this size is impractical, but it would be no problem to equip each retransmitter with a wire antenna, a small balloon, and a cylinder of helium. The standard operating procedures for use of DALS should instruct persons in distress in remote areas or far offshore to send up the balloon antenna before transmitting in order to increase their range. Furthermore, fixed antennas of greater height could become normal installations on commercial vessels which might need a greater range.

It is recommended that when DALS approaches implementation, further research be undertaken to determine the optimum selection of translator antennas and their heights in the various areas where DALS will operate.

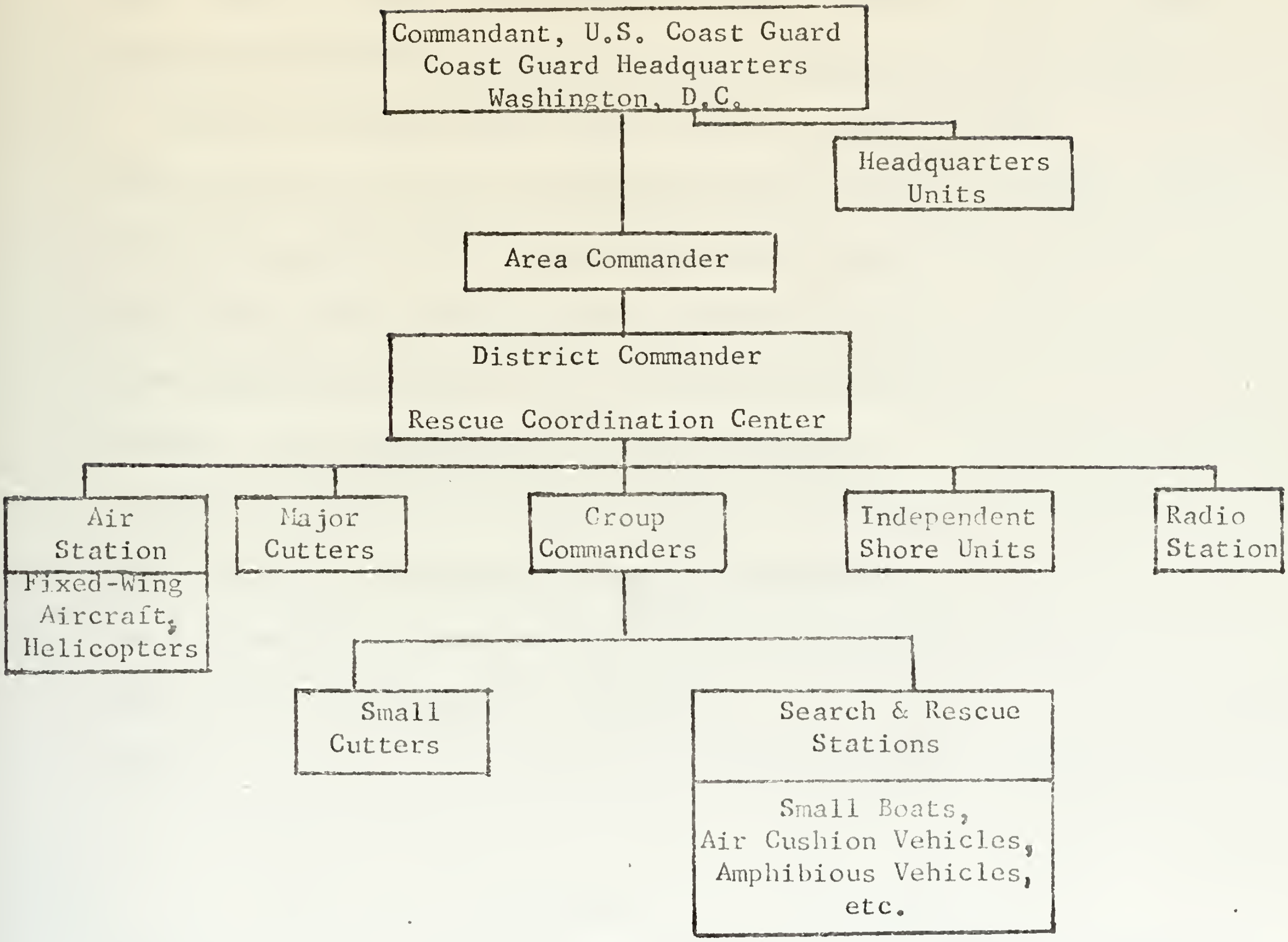


ANTENNA COVERAGE
NEW YORK TO NEWPORT
Rhode Island
Connecticut
Long Island
N.Y.
Translator Station
Seventeen Miles Offshore
Twenty Miles Offshore
Radius "Seen" by Antenna
74W
73W
72W
71W
42N
41N
40N


ANTENNA COVERAGE
ALASKA PENINSULA AND ALEUTIAN ISLANDS
60 N
50 N
40 N
180 W
170 W
160 W
Bristol Bay
Ninety-Mile Radius From Mount Emmons
Mount Emmons
Unimak
Twenty Miles From Coast
Atka
Adak

APPENDIX C.

ORGANIZATION OF THE
UNITED STATES COAST GUARD



APPENDIX D.

TERMS AND ABBREVIATIONS

Base station: Computer center which resolves location of DALS signal.

Coast Guard Auxiliary: volunteer civilian organization which works with the regular Coast Guard to promote boating safety.

DALS: Distress Alerting and Locating System (uses shore station relay.)

EPIRB: Emergency Position Indicating Radio Beacon.

ESSA: Environmental Science Services Administration.

GRAN: Global Rescue Alarm Net (uses satellite relay.)

LO-CATE: Loran-Omega-Course-and-Track-Equipment.

LORAN-C: Hyperbolic electronic navigation aid system.

NASA: National Aeronautics and Space Administration.

Omega: Hyperbolic electronic navigation aid system.

OPLE: Omega Position Location Equipment.

Probability of detection: Percentage chance of finding the object of a search.

R. & D.: Research and Development.

Radiosonde: Weather balloon which transmits upper atmosphere conditions over a small attached radio.

Retransmitter: Remote unit which transmits DALS distress call, identification, and unit position.

RDF: Radio direction finder.

SAR: Search and Rescue.

Sortie: One separate operation by one unit (boat, helicopter, etc.)

Translator: Device which relays DALS signals from retransmitter to base station, or which, when mounted on a rescue vehicle, sends that vehicle's position to base station.

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BSTRACT

Maritime search and rescue is hampered by difficulty in knowing that a vessel in distress, identifying the vessel, determining its location, and directing a scue unit to the scene. The United States Coast Guard has developed and is e-luating an electronic Distress Alerting and Locating System. Basically this stem is comprised of a remote unit on the distressed vessel, which transmits an ergency call, identification, and geographic coordinates from Loran-C and Omega. is data is relayed through a shore mounted translator to a base station where a mputer interprets the information and vectors a rescue craft to the scene. This esis describes the nature of the SAR problem, evolution of the DALS, identifica-on of the problems inherent in the system, and a systematic plan for implementation.

Security Classification

KEY WORDS	LINK A		LINK B		LINK C	
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Search and Rescue						
Distress Communications						
Distress Alerting and Locating System						

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